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Toxic Chemicals Transported by Rail and Public Health Safety using GIS in Montgomery County, Ohio

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Submitted for the degree of

Master of Public Health in Emergency Preparedness

Boonshoft School of Medicine

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Abstract

Hazardous chemicals transported by rail pass directly through urban cities and pose a safety and health threat to the community. Some of these chemicals can be in large quantities, extremely toxic, devastating to the environment and have the potential to cause mass casualties and death. Thousands of people could be in harm's way. While there is always the possibility for accidental chemical release, they also have the potential to be used in acts of sabotage and terrorism. Evaluation of the rail line in Montgomery County, Ohio using standards in the 2008 Emergency Response Guidebook using geographic information systems (GIS) at designated evacuation distances showed that many people, schools, hospitals, nursing homes and public venues are at risk in the event of a chemical release. Using GIS for modeling can help emergency management better coordinate evacuation and shelter in place procedures with the public, plan evacuation routes, and decrease the morbidity and mortality of the exposed. The data collected, by use of GIS, can help give a more inclusive picture of those impacted by a train tanker toxic chemical release and provide evidence for policy review.

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Introduction

Toxic chemicals are transported by pressurized rail cars through highly populated urban areas. These chemicals are necessary to agriculture and industry but can have catastrophic effects in the event of an accident, terrorist attack or sabotage. Currently the transportation industry has no choice and federal regulations forbid refusal to carry chemicals (Analysis: Rail industry caught between cities, federal, and chemical industry preferences, 2006). The information collected in this study can provide evidence to reevaluate policies allowing the transportation industry to more selectively choose the toxic chemicals it transports.

It may not be possible, reasonable or economical to reroute toxic chemicals around highly populated areas, so understanding the effects and potential threat essential. ESRI's ArcGIS Desktop and ArcMap were used to look at the number of people, government buildings, hospitals, health facilities, schools and points of interest within evacuation zones so there can be a better understanding of potential risk. With this understanding, there can be better planning and training should an event involving toxic chemical take place. There can also be better preparation and prevention if a threat is received in general or against a specific target. It may not be possible to stop the release of toxic chemicals; however, being better prepared for any type of event involving a chemical should be a priority.

Statement of Purpose

Montgomery County, Ohio is an urban city with 559,064 residents (U.S. Census Bureau, 2010). There has been little exposure and actual experience in emergency events of this potential magnitude raising the questions: 1) what is the estimated number of residents in harm's way, and 2) what, and where are the other vulnerable populations, and locations, to include schools, hospitals, nursing homes and health facilities, and government facilities within standard evacuation distances of the rail lines. It will be shown that many at risk locations need to be considered when dealing with toxic chemical hazards and that GIS is a great resource to use for emergency planning and management.

Literature Review

The toxic chemicals transported by rail offer potential sources for large quantity chemical release. In the United States 110,000 carloads of toxic chemicals travel over nearly 300,000 (Orum, 2007) miles of rail and pass directly through urban areas. Some of these same chemicals were used as weapons during World War I (Kaplan, 2007). Aside from leakage and derailment, Former White House Deputy Homeland Security Advisor Richard Falkenrath believes these chemicals pose “the single greatest danger of a potential terrorist attack in our country today” (Kaplan, 2007). Toxic chemicals are transported in ninety-ton pressurized rail tanks with little or no security, and at times can be left unattended for days. Fred Miller, a rail security lobbyist and former member of the Washington, D.C. local Emergency Planning Committee called this “pre-positioning weapons of mass destruction” (Kaplan, 2007).

Some estimates suggest that a ruptured chlorine gas tank in a densely populated area could kill, injure and require evacuation of tens of thousands of people (Kaplan, 2007). Because of this it is important to understand what potential threat these chemicals have on the communities they pass through. "A toxic gas cloud release can be lethal to people anywhere within 15 miles of the tracks, depending on the wind direction. The U.S. Coast Guard says that a chlorine gas cloud can spread two miles in ten minutes clearly inadequate time for thousands downwind to evacuate or shelter in place. The U.S. Naval Research Labs has testified that just one chlorine tank car’s cloud released over a major civic or sports event could kill thousands" (Weiss, 2006).

Freight cars carrying chemicals through Montgomery County, Ohio pose potential threat to property and life. There is a great need for heightened security along the rail lines especially in urban areas. Security objectives need to include prevention, deterrence

and public protection when dealing with and planning for chemical events. It is not whether an accident will occur or the likelihood of a terrorist attack but more importantly the ramifications should an event take place.

Pressurized Tank Car

A pressurized tank car is used to transport chemicals under pressure in liquid form. These tank cars are constructed out of insulated steel or aluminum, and have a capacity of up to 33,500 gallons at pressures up to 600 psi. (See Figure 1: Pressurized tank car) (Chemical Response Tool)

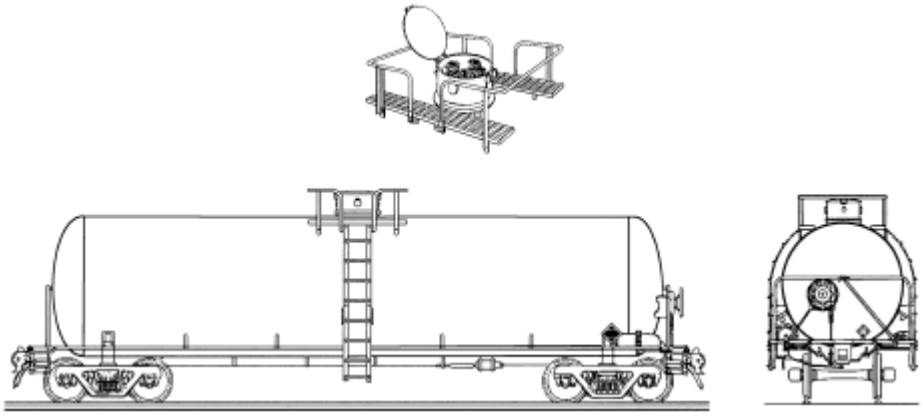

Figure 1: Pressurized tank car
(Emergency Response Guidebook, 2008)

Toxic Chemical Threats

Chemical agents are difficult to produce and deliver in lethal concentrations. Outdoors, the agents often dissipate rapidly. Rail cars contain massive quantities of chemical shipped and stored in densely populated areas. It is this reason terrorists may target rail cars as sources of readymade chemicals, “Terrorists in Iraq have been blowing up chlorine cylinders on trucks, honing their skills” (Solomon, 2010). Again Miller says, "We are putting a lot of people at enormous risk by transporting huge poison gas cargoes through our target cities” (Trains Bring Toxic Targets Through Midstate, 2006).

Chlorine was used for this analysis because it is a widely transported and used potentially lethal toxic inhalation hazard (TIH). It is also one of the world's deadliest chemicals (Solomon, 2010). Chlorine is a greenish-yellow noncombustible gas at room temperature and atmospheric pressure but transported pressurized as a liquid. It is used as a disinfecting agent for drinking water and waste water, and plays an important role in many manufacturing processes. Small doses irritate the eyes, skin, and respiratory tract; large concentrations of chlorine gas can kill people within minutes. If inhaled at very high concentrations, chlorine breaks down in the lungs to form hydrochloric acid that burns lung tissue, causing pulmonary edema and essentially causing drowning as liquid floods the lungs (Centers for Disease Control and Prevention, 2003).

Chemical Accidents

Even though the accident did not involve chlorine it demonstrates the affects of a toxic chemical. In an event close to home, Miamisburg a city in Montgomery County Ohio, white phosphorous, a deadly poisonous gas was spilled during a train derailment. On July 8, 1986 fifteen rail cars containing white phosphorous derailed spilling their contents creating a poisonous cloud of gas requiring a mass evacuation. Two separate evacuations were ordered during the clean up attempts requiring approximately twenty thousand people to be evacuated. The vapor caused by the white phosphorous forced around three hundred residents to seek medical attention for respiratory problems (Miamisburg, Ohio, Train Derailment, 2005). Even two days after the spill two hundred homes were still prohibited from being reoccupied.

In April 1996, a freight train carrying chlorine derailed, in the Clarks Fork Canyon, just outside of Alberton, Montana. The chlorine injured 350 and killed one many were injured permanently. It was the 130,000 pounds of chorine spilled from the

90-ton rail car that was the most threatening. The chlorine gas cloud reached the town of Alberton two miles away. The gas cloud caused the evacuation of nearly 1000 people in about 15 square miles, or a radius of 4 miles (Nordin, 2007).

Another accident on June 28, 2004 in Macdona, TX, involved a collision between two trains and the derailment of four locomotives and 35 railcars. A breached 90-ton railcar released 60 tons (120,000 lbs) of chlorine. The chlorine killed two residents in a nearby house and hospitalized 43 people from inhalation.

The January 6, 2005, accident at Graniteville, South Carolina, was a fatal railway release of a toxic inhalation hazard. Three tank cars containing chlorine derailed, one of which was punctured. The punctured chlorine car initially released 46 tons of chlorine and 14 more over a three day period. This chlorine gas extended at least 2,500 feet to the north of the accident site, 1,000 feet to the east, 900 feet to the south, and 1,000 feet to the west. Emergency responders were dispatched and a reverse 9-1-1 notification told nearby residents to shelter in place until entry teams of emergency responders could evacuate people affected by the gas release. An additional 5,400 people within a one-mile radius of the site were evacuated by law enforcement personnel. The accident caused nine deaths, approximately 554 people were taken to local hospitals, and 75 were admitted for treatment. All casualties were due to chlorine exposure; the NTSB concluded that the accident might have been non-fatal if not for the chlorine release (Nordin, 2007).

Chemical Weapons and Terrorism

Chemicals can be used as weapons of mass destruction and it needs to be understood that terrorism is not just limited to suicide bombers and single explosive devices alone.

According to the Federal Bureau of Investigation terrorism is defined in the *Code of Federal Regulations* as "...the unlawful use of force and violence against persons or property to intimidate or coerce a government, the civilian population, or any segment thereof, in furtherance of political or social objectives" (28 C.F.R. Section 0.85). This means that terrorist may target any group of people and any target regardless of military affiliation putting the lives of the civilian community at risk.

A chemical attack may only harm or cause few casualties, but has a potential for psychological impact, disruption and chaos in affected urban areas (Tucker, 2000). The specific release of a chemical weapon targeting a populous region may be for the purposes of creating terror, fear, or crippling a critical resource, rather than winning a specific battle or war or a specific casualty toll.

Terrorism cannot be overlooked when considering train takers as weapons of mass destruction. Train tankers are considered "soft targets" and remain relatively unprotected against terrorist attack. Terrorists are adaptable and if one kind of target is harder to attack than another they will chose the easier target. In 2004 information was discovered regarding eight schools in six U.S. states coinciding with a deadly siege of a school in Beslan, Russia. There have also been threats against apartment complexes and synagogues. Because there never has been a terrorist attack on a soft target in the United States, the psychological effect would be disastrous, even if the casualty toll were relatively low (Ervin, 2006). Also since there hasn't been an attack on soft targets could possible increase the likely hood of an attack. Finally the FBI has warned that al Qaeda has considered tanker cars as possible targets, "Recently captured al Quadea photographs of U.S. railroad engines, cars and crossings heighten the intelligence community's concer of this threat" (Trains Bring Toxic Targets Through Midstate, 2006).

Methods

GIS Map Creation

Using ArcGIS, maps and tables of Montgomery County, Ohio were generated via geospatial datasets obtained from the U.S. Census Bureau (2000 Census). Information was downloaded at no cost from all websites and transferred into the ArcGIS system. Permission was not needed to obtain data sets; all information is available for public use.

Locations and Facilities Data Set Creation

Geospatial data sets including hospitals, health facilities, government facilities and points of interest were obtained by Google search and compiled in a Microsoft Excel spreadsheet. (See Appendix)

A point on the map represents a specific location. Each map object is defined by a single x, y coordinate pair corresponding to longitude and latitude. Every point object is represented by a symbol.

The school data set was provided by Montgomery County Auditor's Office.

Variable of Interest	**Outcome of Interest**
General Population	Estimated the number of people within the predetermined buffers surrounding the rail line. This was obtained by layering the rail line, buffers, and census dataset within Montgomery County.
Schools, hospitals, health facilities and nursing homes, government facilities and points of interest	Estimate the number of interest areas that are located within the predetermined buffers of the rail line. Locations that lie within each buffer will be totaled and calculated into percentages by taking the number of each location within each buffer and divided it by the total number of locations for each area of interest.

Geocoding with Google Earth

Google Earth software was used for the Geo coding of the facilities' address. Google Earth is an OpenGL free satellite and referencing software (Google Earth, n.d.).

Evacuation Zones (Buffers)

The intervals analyzed are the recommended evacuation distances as per the 2008 Emergency Response Guide for the chemical Chlorine. The evacuation distances vary depending on the size of the spill and the time of day and range from .3 miles for small spills during the day and 1 mile during the night. For large spills the evacuation distances

range from 2.2 miles during the day and 5 miles during the night (Emergency Response Guidebook, 2008). "It is important to note that Protective Action Zones do not only depend on the mere presence of gases/vapours but mainly on its concentration in the air:

During the day, there is an increase of the atmospheric disturbances creating a greater dispersion (dilution) of the gases/vapours, which results in a weaker toxic concentration in the air and thus requires a smaller Protective Action Zone than at night.

During the night, the gases/vapours will calmly dissipate. This will result in a higher toxic concentration in the air and consequently, necessitate a greater Protective Action Zone" (Power Point Presentation for Training, 2009).

Table 1 - Table containing Chlorine from the Emergency Response Guidebook 2008.

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TABLE 1 - INITIAL ISOLATION AND PROTECTIVE ACTION DISTANCES

ID No.	NAME OF MATERIAL	SMALL SPILLS (From a small package or small leak from a large package) First ISOLATE in all Directions Meters	(Feet)	Then PROTECT persons Downwind during- DAY Kilometers (Miles)	NIGHT Kilometers (Miles)	LARGE SPILLS (From a large package or from many small packages) First ISOLATE in all Directions Meters	(Feet)	Then PROTECT persons Downwind during- DAY Kilometers (Miles)	NIGHT Kilometers (Miles)
1005 1005	Ammonia, anhydrous Anhydrous ammonia	30 m	(100 ft)	0.1 km (0.1 mi)	0.2 km (0.1 mi)	150 m	(500 ft)	0.8 km (0.5 mi)	2.3 km (1.4 mi)
1008 1008	Boron trifluoride Boron trifluoride, compressed	30 m	(100 ft)	0.1 km (0.1 mi)	0.6 km (0.4 mi)	300 m	(1000 ft)	1.9 km (1.2 mi)	4.8 km (3.0 mi)
1016 1016	Carbon monoxide Carbon monoxide, compressed	30 m	(100 ft)	0.1 km (0.1 mi)	0.1 km (0.1 mi)	150 m	(500 ft)	0.7 km (0.5 mi)	2.7 km (1.7 mi)
1017	Chlorine	60 m	(200 ft)	0.4 km (0.3 mi)	1.6 km (1.0 mi)	600 m	(2000 ft)	3.5 km (2.2 mi)	8.0 km (5.0 mi)

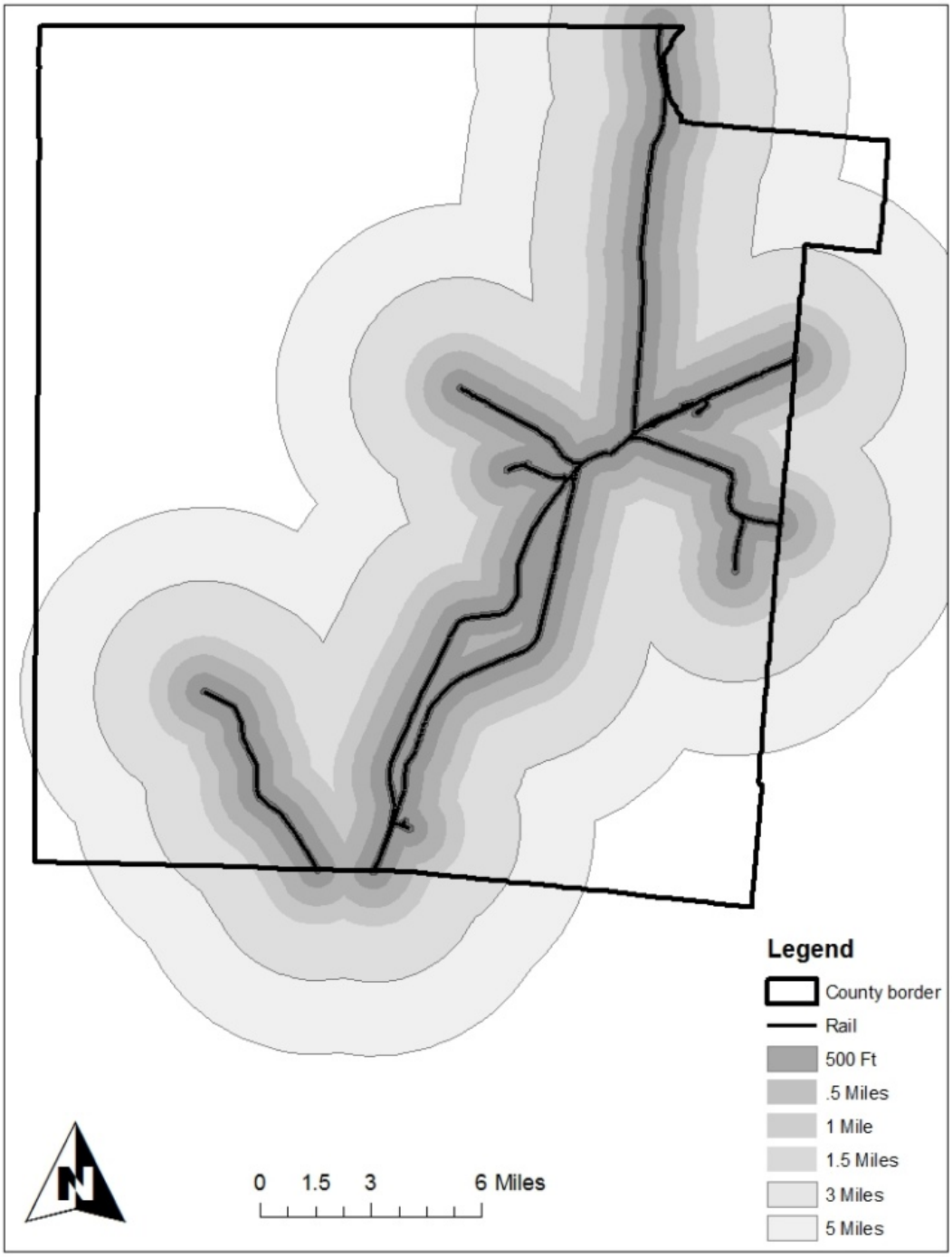

Figure 2: Rail lines and evacuation zones

The buffer defined a zone around the rail line measured in units of distance equal to 500 foot, .5 miles, 1 mile, 1.5 miles, 3 miles, and 5 miles (see Figure 2). This buffer was useful for proximity analysis and to calculate the number of items in each category. "Select by location" was used to count the number of items which have their centroid, or geographic center, within the buffer. Each query used a defined distance from the rail and calculated the number schools, health facilities and nursing homes, hospitals, government buildings and points of interest within the buffer distance. The query produced a table listing all items that were within that buffer's distance. The attributes table was then used to count the number of items associated with each "select by location" query. (See Table 4 - All items of interest, quantified by layer with percentages)

Chemical Spill: A Disaster Scenario

Picture a train derailing or exploding, just before noon, around a junction point in downtown Dayton, Montgomery County Ohio. Derailed cars accordion, and a tanker car filled with 30,000 gallons of chlorine ruptures. The chemical and its irritating, corrosive vapor, which causes chemical burns to the skin, eyes, nasal passages, throat and lungs, spill out a massive hole on each tank. Metal-on-metal collisions spark a fire that burns some of the chemical, creating additional toxic gases. The prevailing winds blow the "hot zone" — the area immediately dangerous to life and health — toward downtown. Chlorine vapors, which are heavier than air, spread in low areas.

The Dayton Fire Department decides to initially evacuate an area 2 miles in all directions according to the 2008 Emergency Response Guidebook for a large spill (Emergency Response Guidebook, 2008).

Hospitals affected considered the type of event, including its expected arrival time,

magnitude, area of impact, and duration; and the anticipated effects on both the hospital and the community, given the nature of the event and the results of their pre-disaster self-assessment to decide whether to evacuate or shelter-in-place. Five local hospitals, including Children's Medical Center, Dayton Heart Hospital, Grandview Hospital, Kindred Hospital and Miami Valley Hospital are required to shelter in place and are restricted from accepting new patients as they prepare to handle as many contaminated victims as possible. Initially hospitals triaged for "high risk" patients then did the best they could to help the rest.

The remaining local hospitals are overwhelmed with victims and the walking wounded. People exposed to the plume need to be decontaminated. Many of the victims need oxygen or a ventilator and will require respiratory care for a long period of time.

This kind of accident could kill or injure thousands of people in downtown Dayton, Montgomery County. In the aftermath, contaminated buildings shut down for up to two months, so surrounding businesses either close or severely limit operations during that time, having a dire effect on the regional economy.

The criteria in this scenario were based on actual chemical tanker derailments and accidents. For example the accident in Graniteville, South Carolina, involved trains colliding because of an improperly lined railroad switch. This location has a multiple switch points before and after the accident site. The two mile distance was chosen because it is the recommended isolation distance for a large spill during the day (Emergency Response Guidebook, 2008). Finally, this site was chosen because of its location in the heart of downtown Dayton and from an accident or terrorist standpoint had the potential for a worst case scenario.

Results

The results generated from the analysis are estimates only and will not be all inclusive. The targets of interest for this study included population, schools, health facilities and nursing homes, hospitals, government buildings and points of interest. Below is the total for each area of interest in Montgomery County, Ohio.

Table 2 - Items of interest in Montgomery County

Population	559,064
Schools	236
Health care facilities	54
Hospitals	12
Government	7
Points of interest:	11

There were 559,064 residents in Montgomery County used for this study. GIS population mapping showed that 9973 people within the at 500 foot buffer to 494,942 people within the 5 mile buffer (2% to 89% respectively) live within five miles of the rail line. (See Table 4 - All items of interest, quantified by layer with percentages)

There were a total of 236 schools in Montgomery County in this data set, however it only included schools elementary thru high school; colleges were considered points of interests due to their higher profile nature and limited number. The number of schools within the buffer zones was 12 schools within 500 foot buffer to 231 schools within the 5 mile buffer (5% to 91% respectively). (See Table 4 - All items of interest, quantified by layer with percentages) A limitation is that the school data sets used is several years old and likely out of date at the time of this study.

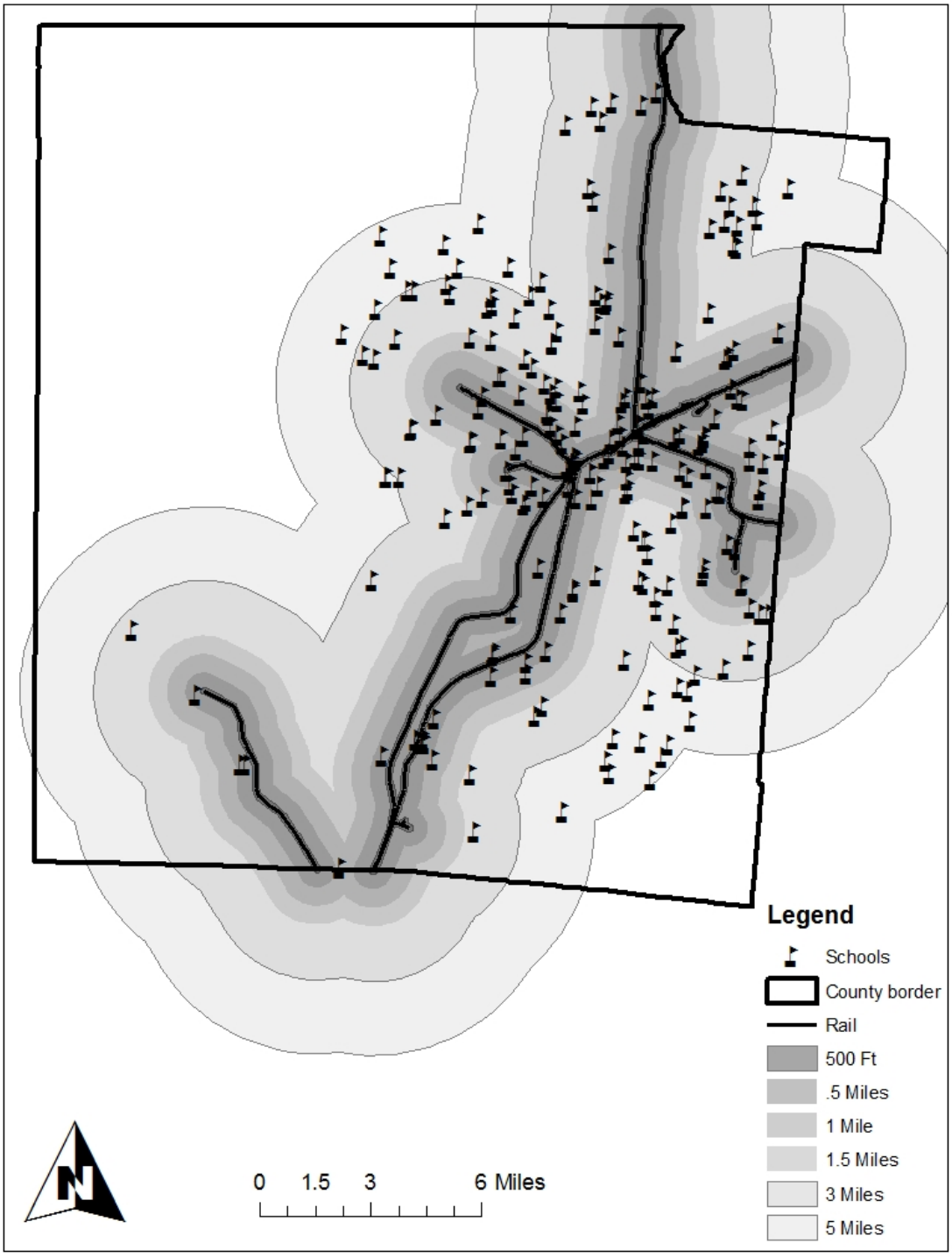

Figure 3: Schools within evacuation zones

The analysis considered 54 nursing homes and extended care living facilities and dialysis centers. It ranged from 0 nursing homes within the 500 foot buffer to 52 nursing homes (0 – 96%) within the five mile buffer. (See Table 4 - All items of interest, quantified by layer with percentages) The geocoded list of facilities included in this analysis can be found in the appendix. (See Table 5 - Special needs populations: nursing homes, extended stay living facilities and dialysis centers with geocoding)

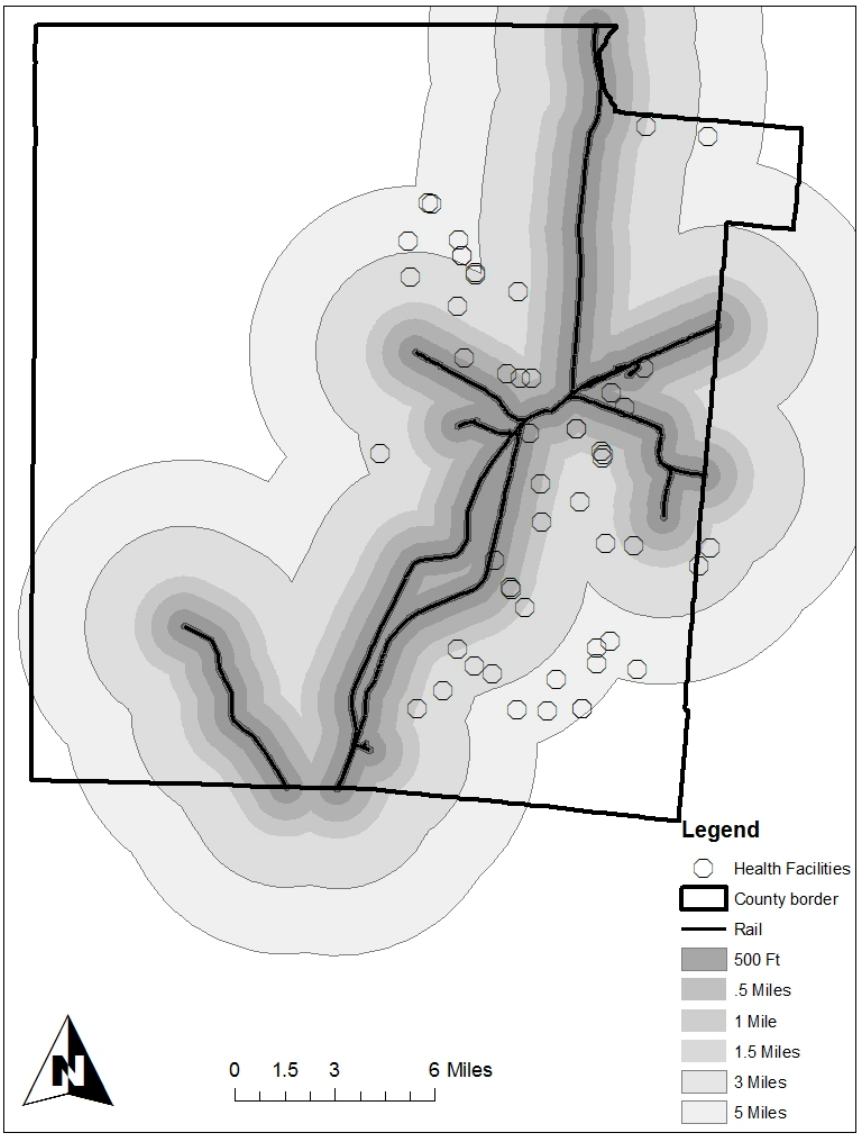

Figure 4: Health Facilities and Nursing Homes within evacuation zones

Montgomery County has 12 hospitals, 11 are within the five mile buffer from the rail. The proximity of hospitals to the rail ranged from 0 hospitals within the 500 foot buffer to 11 hospitals (0 – 92% respectively) within the five mile buffer of the rail. (See Table 4 - All items of interest, quantified by layer with percentages) The geocoded list of hospitals can be found in the appendix. (See Table 6 - Montgomery County, Ohio hospitals with geocoding)

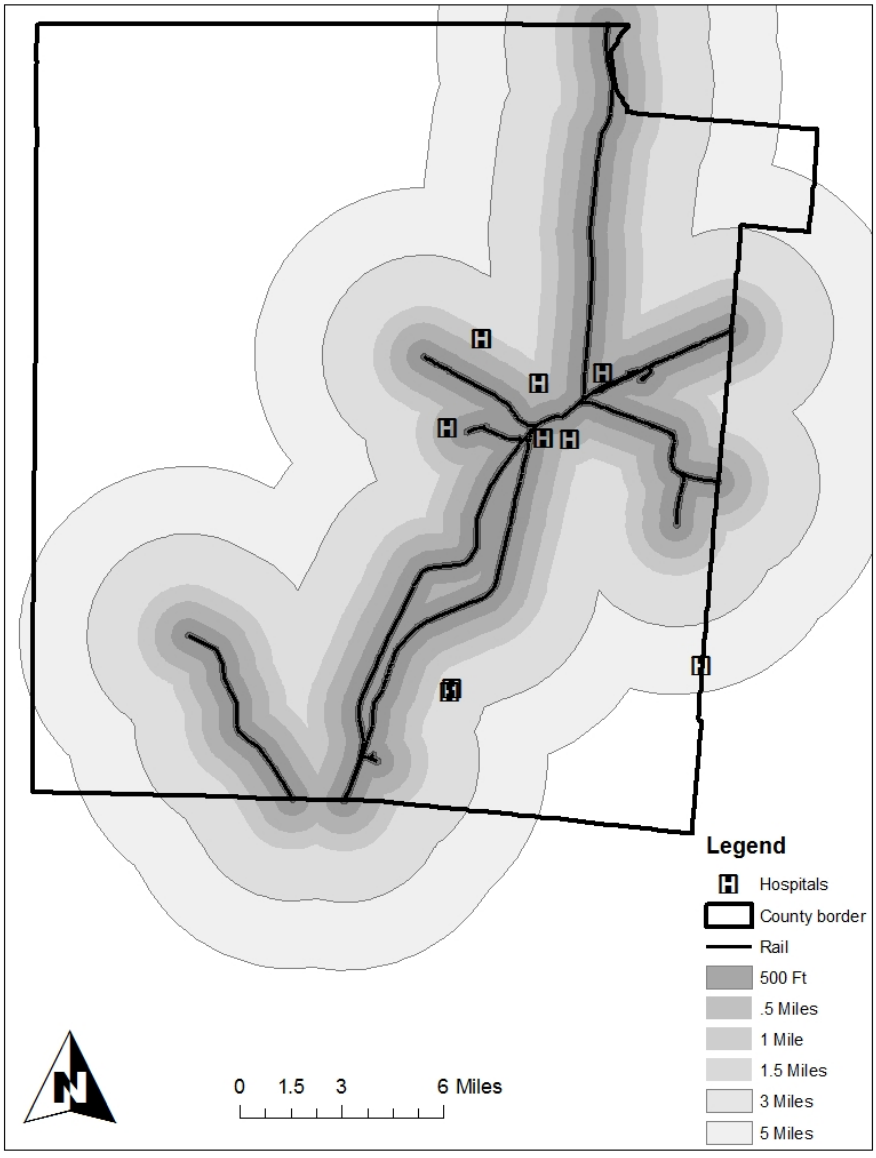

Figure 5: Hospitals within buffer zones

There were a total of seven government buildings and all seven are within a half mile from the rail. (See Table 4 - All items of interest, quantified by layer with percentages) The geo coded list of hospitals can be found in the appendix. (See *Table 8 - Montgomery County, Ohio Government Buildings with latitude and longitude geocoding*)

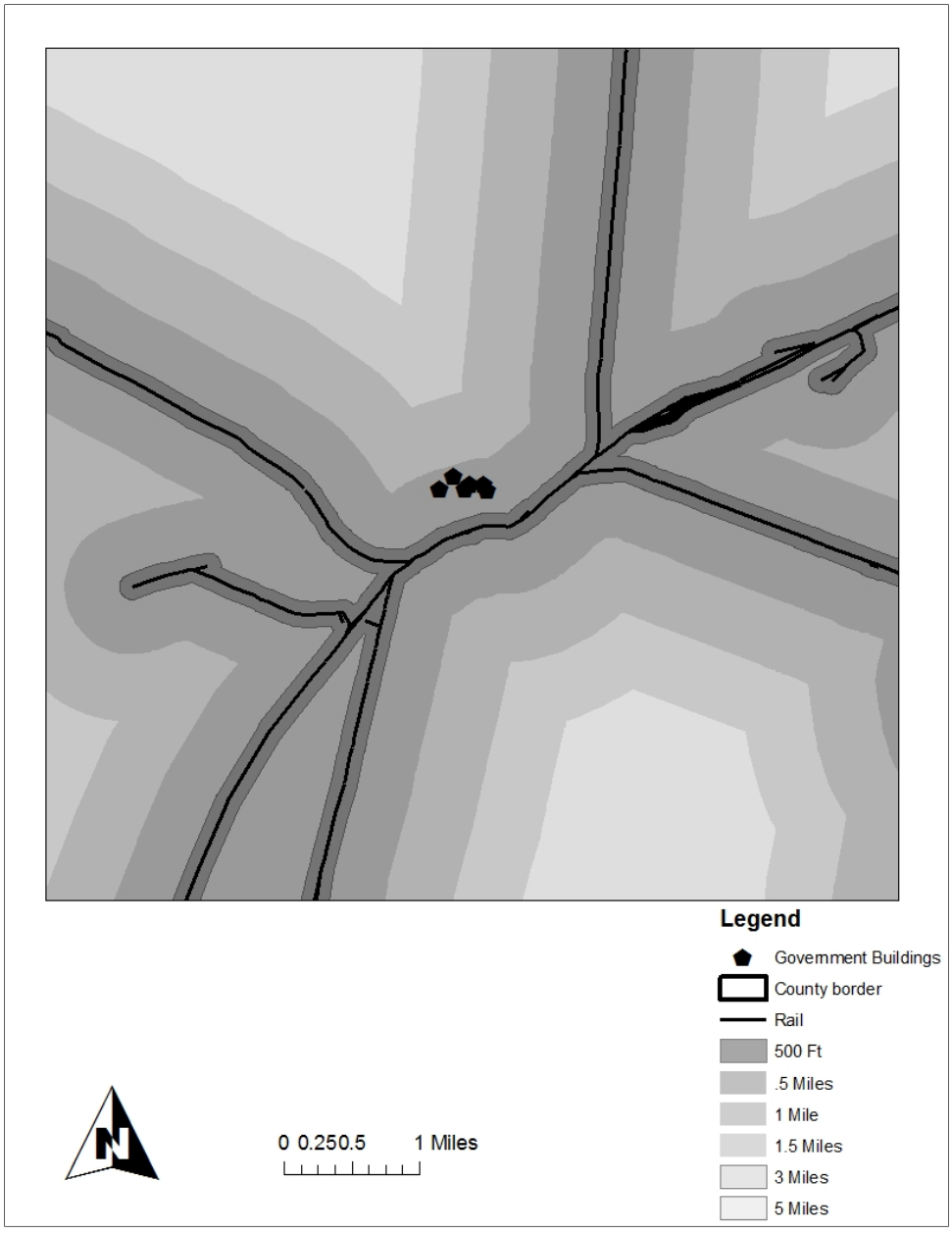

Figure 6: Government buildings within evacuation zones

There were 12 points of interest in this analysis. All of the locations selected fell within the three mile buffer of the rail. (See Table 3 - Items of interest affected during chemical spill scenario) The geocoded list of hospitals can be found in the appendix. (See *Table 7 - Montgomery County, Ohio points of interest with geocoding* and Table 6 - Montgomery County, Ohio hospitals with geocoding)

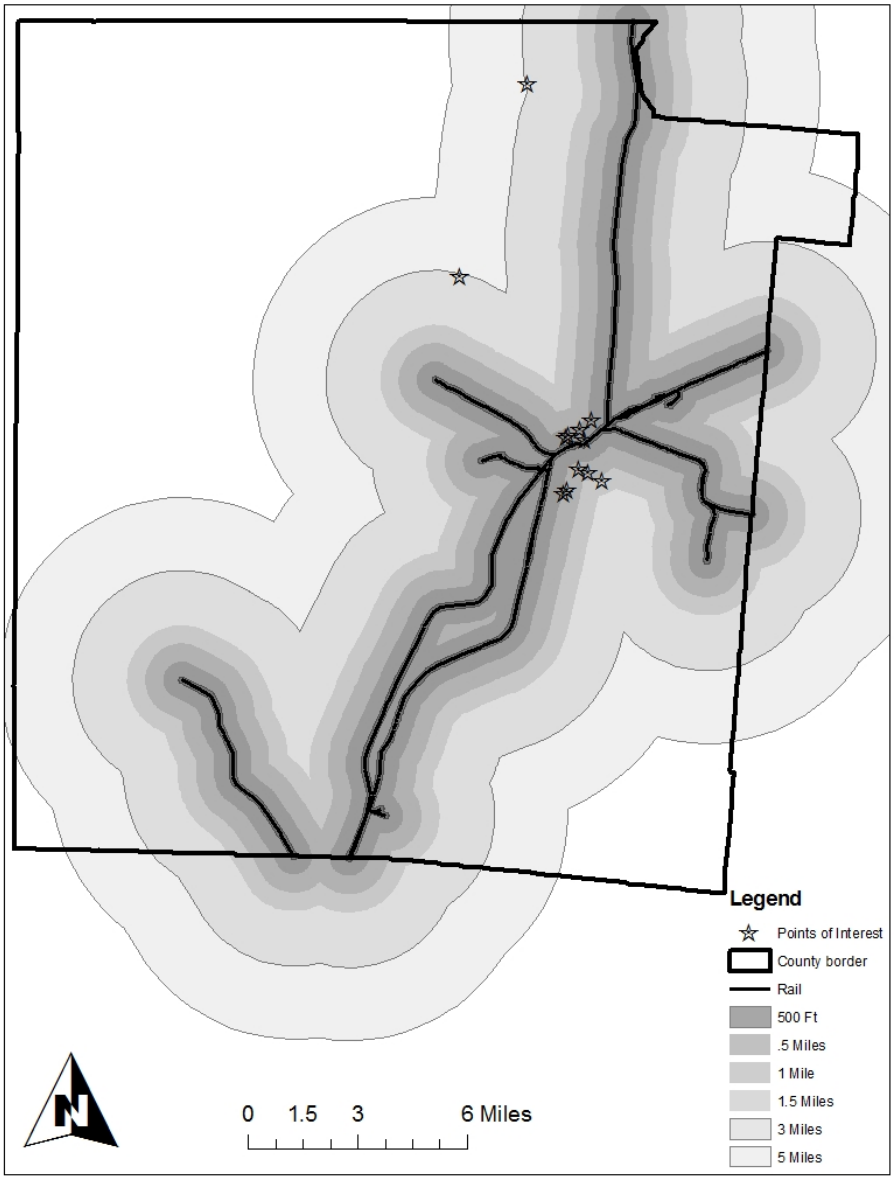

Figure 7: Points of interest within buffer zones

The layers were combined to give a total picture of all areas of interest. This analysis is based on the scenario presented in this paper with an evacuation distance of two miles. The data shows that the government buildings chosen are the highest risk because all seven Montgomery, County buildings are within two miles of the scenario site. Population was the lowest at .2% of total county population within two miles of the scenario site. (See Table 3 - Items of interest affected during chemical spill scenario)

Table 3 - Items of interest affected during chemical spill scenario

Title	**Quantity**	**Total**	**Percentage**
Schools	49	236	20.8
Hospitals	5	11	45.5
Government	7	7	100
Points of Interest	8	12	66.7
Healthcare Facilities	9	52	17.3
Population	1235	494,942	.2

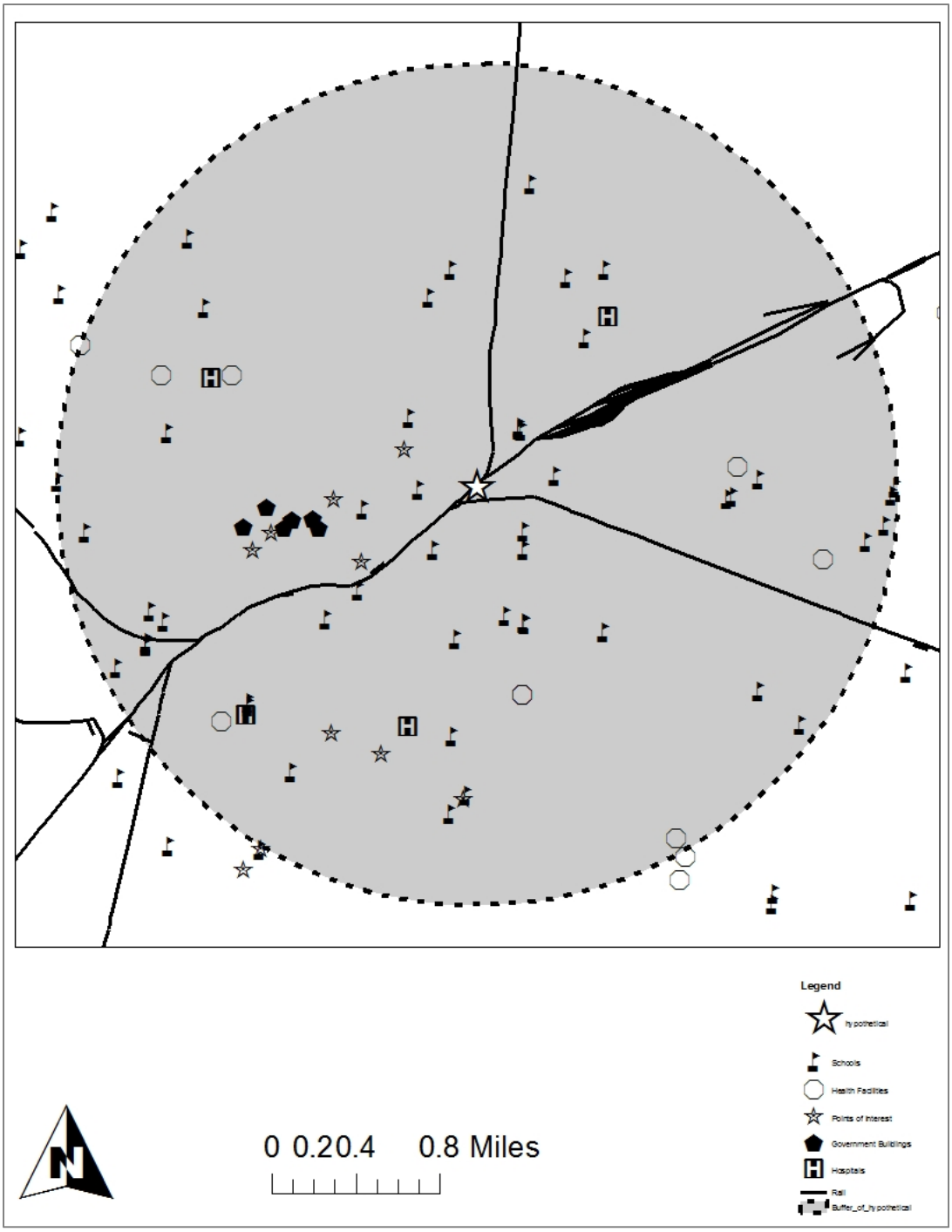

Figure 8: Compilation of all layers for scenario

Discussion

Thousands of people could be impacted during a chemical accident. Vulnerable populations, points of interest, hospitals and government facilities are important because they have an impact on the economy as well as the physical and psychological well being of the local community and health care system.

Problems after an accident may include interstates needing to be shut down for days creating a transportation bottleneck and people denied access to their places of employment, homes and property during this period. Economic effects may be felt for many years afterwards, including road repair from detoured traffic, and lawsuits due to injuries. Detour roads may not handle the increased traffic, and detours can extend for miles and some large vehicles may not even be able to take the detour. Finally the impacted buildings, along with public and private property could costs millions of dollars for repair and decontamination or replacement (Nordin, 2007).

Estimating the number of people within a certain distance along the entire rail line does not mean that many people are at risk at the same time. There are a large number of people along the rail line at risk during a chemical event, however according to the scenario presented only .2% of the total county population is at risk and possibly requiring evacuation. (See Table 3 - Items of interest affected during chemical spill scenario) These population estimates may allow responders and receiving health facilities to be prepared for the additional patient burden.

The number of schools within the possible threat zone is important to know for multiple reasons. One reason is so that schools, at higher risk, can develop and practice evacuation or shelter-in-place drills. Another reason to look at schools is because they have a lot of people, especially children, within a confined space. The physical

characteristics of a child make them more vulnerable to chemical exposure. A child's statue is closer to the ground possibly exposing them to more dense vapors. Children also have enhanced absorption because of their higher skin surface its permeability. Children breathe approximately twice as fast increasing respiratory absorption (Why Are Children More Vulnerable to Chemical Pollutants, 2009).

First responders and emergency crews need to be prepared for the amount of resources and man-power necessary to deal with the situation. It is also important to understand that children have a different set of needs and will require special attention. According to the scenario presented 20% of the schools, in Montgomery County, would be affected and require to shelter in place or evacuate. (Table 3) Schools away from the rail lines and outside of the contaminated area should be selected as designated shelters. A school building can be provisioned as a community shelter for people in exposed or contaminated areas offering resources like locker rooms, storage, and kitchens. The principal or designated member of the staff of the school being used should be someone familiar with the building to be used: its size, facilities, and day-to-day level of supplies. The schools representative should be prepared before the accident and prepared during an event to serve under agreements in effect between the school board and the Red Cross (American Red Cross Guide for Shelter Managers, 1988).

Nursing homes and health care facilities (ex. dialysis centers), like schools, maintain a lot of people many of which will require special transportation needs, oxygen, medications, etc. It would be prudent planning to know, if an evacuation is ordered, how many people would need special transportation and the number of public and private ambulance services available. Using GIS to map out locations can help responders know exactly which facilities need to be evacuated first, evacuation routes available and the

location of the nearest receiving facility.

Hospitals are probably the most important location to look at when considering chemical spills. People will be looking for a place to go, regardless of the level of contamination, seeking help. Whether the spill is accidental or an act of terrorism the vapor cloud and evacuation distance can be extensive. As demonstrated in the scenario, in Montgomery County it is possible for many hospitals to be within the contaminated area. Most likely the entire hospital would not be evacuated, however they may not accept new patients, and people may be required to shelter in place. This could pose a serious problem because victims of a toxic chemical exposure are likely to seek help from the closest hospital which may be within the contaminated area. According to the scenario five out of the 11 or 46% of the hospitals in Montgomery County would fall within the contaminated area requiring people to shelter in place or evacuate. It is important when planning to consider for evacuation and dispersal of victims for a case where the nearest hospital is not available. Establishing or periodically updating mutual aid agreements with adjacent counties and having preplanned scenarios, like the one in this paper, can help hospitals know where to send people quickly reducing travel time, exposure and time to treatment.

Not all government buildings in Montgomery County were included in this study, only those government entities with past history as targets or locations of high risk due to the nature of their business (See Appendix). Government buildings, or buildings with government offices such as the Alfred P. Murrah building in Oklahoma City, the New York City World Trade Center, the Pentagon, U.S. Post offices, Federal Bureau of Investigation and other law enforcement and other public service entities may be primary targets for attack due to some personal or political agenda. It is also important that the

"local Government" stays strong in times of emergency because the community will be turning to them for answers and guidance. If an attack or accident does affect the government building preplanning of alternative locations for operations would be prudent. According to the scenario this should actually be a high priority because 100% of the government buildings looked at are affected.

Points of interest (POI) may be targets and need to be considered because of symbolism or population density. POIs include colleges, sports venues, air ports and arenas. If a credible threat is received against a point of interest it will be important to know the number of POIs in an area, where they are located and how many people may be affected. For example sporting and entertainment venues can have thousands of people in attendance during an event. In Montgomery County, Ohio the University Dayton Arena can seat 13,455 people (UD Arena, n.d.), the Hara Arena has a 5,500 person permanent seating capacity (Hara Arena, 2010) and Fifth Third minor league baseball field seats 7,230 people (About Fifth Third Field, 2011).

Colleges can have thousands of people in a single location. In 2009 the University of Dayton had a population of 7,406 enrolled undergraduate students and about 11,000 total students (University of Dayton, 2009) and Sinclair Community College has a population of 19,466 enrolled full and part time students (Sinclair Community College, 2011). It's highly unlikely all roughly 30,000 students will be on campus at one time, however thousands of students will be. When dealing with college campuses more concern needs to be taken during the day and during the regular school year and less during the night and during breaks. This information will help with planning response times, personnel and resource demands and evacuation routes and times.

All the layers were combined to give an aggregate picture of Montgomery County as part of a disaster scenario. The scenario included the estimated population and locations within a two mile radius evacuation zone. (See Table 3 - Items of interest affected during chemical spill scenario) According to the scenario residential population may not be as much of a resource priority as the other locations because fewer people could be at risk as compared to the other locations. Only 2 percent (1,235 people) of the population was at risk for exposure whereas almost 50% of the hospitals, 70% of the points of interest, and 100% of the government buildings could be at risk. Some of these points of interest include colleges with nearly 30,000 students and entertainment venues with over 25,000 people potentially at risk. This is the kind of information that can help emergency responders use their man-power and resources efficiently during an event.

Further analysis using Computer-Aided Management of Emergency Operations (CAMEO) and Areal Locations of Hazardous Atmospheres (ALOHA), developed by the National Oceanic and Atmospheric Administration, during a scenario or actual event could allow responders to make an educated guess about just how far away adverse effects of the chlorine might be felt, as well as the infiltration of dwellings.

This data is important for planning when considering the four phases of emergency management, mitigation, preparedness, response and recovery. The data gathered can help in all phases but more specifically when dealing with mitigation and preparedness. Mitigation is primarily about prevention and planning for future emergencies or minimizing their effects. For emergency events it is important that this step take place before the emergency. Using these models can help emergency management and response personnel get a better understanding of who is at risk and what may be high priority targets.

Preparedness is another key component when planning for future emergency events. By using this data a better understanding can be gained about what it will take to handle an emergency situation involving toxic chemicals. By better understanding how many and where at risk people may be located evacuation routes and supplies can be properly estimated before the event takes place.

When dealing with mass casualty chemical events resources are of the utmost importance. These resources should include adequate protective equipment and supplies. Events of this nature also need to consider decontamination procedures and locations including portable decontamination as well as public facilities. Complacency regarding large scale chemical events and underestimation of demand and resources could lead to higher casualties and decreased safety for responders.

Planning and preparedness is even more important in today's economy to better utilize the manpower and resources available due to budget reductions. The city of Dayton, Ohio for example is facing a $5 million operating budget reduction for the 2011 fiscal year. This operating budget includes funding for fire and police. In order to save money 89 positions will be cut of which include fire personnel and vacated position in police departments will not be filled after a time when 165 police and fire positions have been cut since 2001 (Sullivan, 2010). Fire and police departments are important for response, notification and security but with a reduced workforce it will become even more important to work smarter and utilize all tools and technology available.

Data Limitations

The modifiable areal unit problem (MAUP) is the idea that the interpretation of a geographical phenomenon within a map depends on the scale and partitioning of the areal units that are imposed on the map (Ratcliffe, 2007a). This needs consideration because the data was only examined at one spatial level and the results may have differed with a different spatial unit. This is because larger tracts may have more people however smaller tracts may have more people per square mile – a higher density (What Can You Do with GIS?, 2011).

When dealing with estimated data sets and general populations it is necessary to consider ecological fallacy when interpreting the results. Ecological fallacy is the logical fallacy of using generalized data to make precise conclusions. It can also go the opposite way by using an acute or specific instance and generalizing it to a large population. It may be true that the populations and locations located within five miles of the rail line are at heightened risk of chemical exposure during the event of a rail tanker car accident or sabotage it does not mean that exposure is certain (Ratcliffe, 2007b).

The numbers represented in this study were estimates and primarily for reference only. The data relies on information provided by third party applications and self reported census databases. Other factors that may influence some of the risks associated with the locations presented may include, but not be limited to, the time of the year, special events, employment rates and time of day. For example the census data is the nighttime population, they daytime population is going to be different.

Finally locations such as daycare centers, religious venues and churches and parks were not considered for this analysis. Leaving these items out does not indicate that they

would not be at risk or are less important and the end result is still the same.

Conclusion

Based on the maps generated, locations and thousands of people along the rail line in Montgomery County, Ohio could be vulnerable and at risk in the event of a large scale chemical release. Not only residents in homes but additional locations like schools, hospitals, health facilities and nursing homes, government buildings and points of interest, and more may be affected during such an event. Emergency personnel need to see who and where the people in their community may be affected the most. Understanding the situation can help emergency personnel be better prepared and help reduce or prevent long term morbidities related to chemical exposure. With GIS technology it is possible to evaluate multiple interest areas for better policy development and lead to more effective communication, shelter-in-place and evacuation plans, as well as, hospital preparedness and better training. Planning for disasters is multivariable and involves many departments within the public and private sectors for creating policies regarding the county's emergency preparedness.

Future studies involving chemicals may include using GIS for planning the placement of mobile units and including the locations of urgent care facilities and doctor's offices to help with demand. Another important consideration, when dealing with a chemical accident, is entrance and egress of traffic into the contaminated area. Using GIS emergency management could run similar scenarios and predict traffic patterns and plan for emergency evacuation routes and efficient routes for emergency vehicles and personnel. Finally since the landscape of any city is not perfectly flat it would be beneficial to use topographical models to estimate low lying areas where

chemicals could collect. The vulnerable populations within low lying areas could be notified first during a chemical accident involving chemicals like chlorine because they remain close to the ground and would collect in the lowest lying areas. This data would provide more detailed information for areas of contamination.

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Table 4 - All items of interest, quantified by layer with percentages

	Population	%	Schools	%	Health Facilities	%	Hospitals	%	Government Buildings	%	Points of Interest	%
500 feet	9973	2	12	5	0	0	0	0	0	0	1	8
.5 Miles	96711	17	76	32	5	9	3	25	7	100	5	42
1 Mile	185807	35	121	51	13	24	5	42	7	100	9	75
1.5 Miles	265871	48	146	62	20	37	8	67	7	100	10	83
3 Miles	422149	76	205	87	36	67	10	83	7	100	12	100
5 Miles	494942	89	231	98	52	96	11	92	7	100	12	100
Total	559064		236		54		12				12	

Appendix

Table 5 - Special needs populations: nursing homes, extended stay living facilities and dialysis centers with geocoding

Facility Name	Latitude	Longitude
Alterra Sterling House of Englewood	39.872589	-84.310426
Alterra Sterling House of Washington Twp.	39.626155	-84.169372
Arbors of Dayton	39.745547	-84.201879
Avalon At Otterbein	39.723471	-84.194746
Bethany Village	39.652768	-84.161897
Brighton Gardens Assisted Living	39.645846	-84.161259
Caremore Assisted Living	39.669385	-84.202536
Caremore Assisted Living Housing	39.655626	-84.154126
Carriage Inn at Dayton	39.814828	-84.234147
Countryview Manor	39.735538	-84.285784
Crestview Nursing Home	39.697099	-84.098701
Dayton Center for Dialysis North - Turner Rd	39.813704	-84.233831
Dayton Center for Dialysis South - Springboro Pk	39.689839	-84.219917
Dayton Regional Dialysis South - Wash. Village	-84.219917	-84.196247
Dayton Regional Dialysis North - Huber Heights	39.875817	-84.103889
Elmcreek Nursing Home	39.650864	-84.239845
Elmcroft Assisted Living - Miamisburg	39.625171	-84.206085
Forestview Nursing	39.769439	-84.20144
Friendship Village	39.827755	-84.272228
Grafton Oaks	39.769380	-84.207767
Grand Court Kettering	39.689174	-84.104768
Heartland of Centerville	39.643528	-84.138500
Heartland of Kettering	39.697343	-84.141854
Heartland of Miamisburg	39.632965	-84.247918
Hospice of Dayton	39.735238	-84.160652
Kingston of Miamisburg	39.624829	-84.261983
Liberty Ret. Centerville - Assisted Living	39.638583	-84.183864
Lincoln Park Manor	39.698252	-84.157710
Livingston Care Center	39.757555	-84.148371
Maria Joseph Living Center	39.812280	-84.270537
Mary Scott Nursing Home	39.777653	-84.239268
McEwen House	39.624676	-84.188812
Mercy Siena Gardens	39.821839	-84.241826
Mercy Siena Woods	39.821839	-84.241826
Northwood Nursing and Rehab	39.800225	-84.243958
Oaks of West Kettering	39.706996	-84.194154
Oregon Place Rest Home	39.747768	-84.174999
Riverside Nursing Home	39.806729	-84.209384

Sanctuary at Wilmington Place	39.736834	-84.160128
Somerville at South Dayton	39.643957	-84.230379
South Park Assisted Living	39.747768	-84.174999
Spring Creek Nursing HOme	39.879583	-84.139125
Spring Hills at Singing Woods	39.828702	-84.243865
St. Leonards Nursing Home	39.622249	-84.134698
Sterling House of Washing Twp.	39.626155	-84.169372
Stillwater Center	39.844010	-84.259331
Sunrise of Clayton	39.844737	-84.261526
Sunrise of Oakwood	39.715824	-84.172394
Ten Wilmington Place	39.738114	-84.161022
The Suites at Walnut Creek	39.677082	-84.210590
Victorian Manor	39.771296	-84.215034
Walnut Creek Nursing Home	39.678195	-84.210837
Waterford Assisted Living	39.640278	-84.220234
Whispering Meadows	39.774649	-84.137640
Widows Home	39.763811	-84.156169

Table 6 - Montgomery County, Ohio hospitals with geocoding

Facility Name	**Latitude**	**Longitude**
Children's Medical Center	39.773970	-84.167966
Dayton Heart Hospital	39.787783	-84.234928
Dayton VA Medical Center	39.749384	-84.253141
Good Samaritan	39.787783	-84.234928
Grandview Hospital	39.769292	-84.203321
Kindred Hospital	39.746047	-84.199662
Lifecare Hospitals	39.638340	-84.248158
Miami Valley Hospital	39.745474	-84.185228
Miami Valley Hospital South	39.650077	-84.110239
Samaritan North Health Center	39.854386	-84.274313
St. Elizabeth Urgent Care	39.746047	-84.199662
Sycamore Hospital	39.636693	-84.249039

Table 7 - Montgomery County, Ohio points of interest with geocoding

Facility Name	Latitude	Longitude
Dayton International Airport	39.897403	-84.222664
Fifth Third Field	39.764538	-84.185961
Hara Arena	39.820515	-84.255237
Dayton Convention Center	39.756801	-84.189542
Montgomery County Fairgrounds	39.743558	-84.187466
Montgomery County Jail	39.758606	-84.197652
Schuster Performing Arts Center	39.761000	-84.192222
Sinclair Community College	39.757393	-84.199358
St. Vincent Homeless Shelter	39.744925	-84.192038
University of Dayton	39.740539	-84.180085
University of Dayton Arena	39.735424	-84.199668
Welcome Stadium	39.736875	-84.198123

Table 8 - Montgomery County, Ohio Government Buildings with latitude and longitude geocoding

Facility Name	Latitude	Longitude
Dayton City Hall	39.759620	-84.194052
Downtown Dayton License Bureau	39.758970	-84.200160
Montgomery County Courts-Civil	39.758981	-84.196579
Montgomery County Sheriff-Civil	39.760422	-84.198157
Social Security Information: Dayton Office	39.759542	-84.195877
U.S. Post Office	39.759019	-84.193515
US Social Security Administration	39.759542	-84.195877